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ABSTRACT

A course is described which was designed to: (1) teach correct use of the calculator; (2) teach appropriate techniques for solving arithmetic problems using the calculator; and (3) develop number sense in students through teaching of appropriate facts, concepts, and techniques to be carried out mentally without the calculator. (Number sense starts out with some sort of "feel" about the size of a number and extends upwards to include such mental arithmetical skills as estimation.) The course consists of 20 teaching/working units each recorded on one side of a cassette tape. Concepts covered in the units include: introduction to calculator; addition; subtraction; means; multiplication; division; percentages; decimals; and proportion. Teaching strategies and experiences during the 5-day course, results of course and pre/post-tests taken by the 24 participants, students' assessment of the course, and seven minor amendments to the course based on feedback are discussed. It is indicated that the results of the pre/post testing are of little value due to the methodology employed. (JN)

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NUMERACY PROJECT

CALCULATE and ESTIMATE

A REPORT ON THE BACKGROUND AND CONDUCT OF A COURSE

HELD AT THE ADMINISTRATIVE COLLEGE

OF

PAPUA NEW GUINEA

MARCH 7 - 11, 1983

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ADMINISTRATIVE COLLEGE OF PAPUA NEW GUINEA

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CALCULATE AND ESTIMATE

A REPORT ON THE BACKGROUND AND CONDUCT OF A COURSE HELD AT THE ADMINISTRATIVE COLLEGE OF PAPUA NEW GUINEA, MARCH 7 - 11, 1983

Background

The production of cheap calculators with long-life batteries only began around 1980 and mathematical educators world-wide have not yet really adjusted their syllabuses to meet this entirely new situation.

It is obvious that in the future anyone whose work will be made easier with a calculator is likely to have one, and if it goes wrong (which seldom happens with the new LCD calculators) or is broken, they will borrow someone else's rather than try to remember any complicated procedures which they may have been taught when they had no calculator.

It is therefore safe to base our teaching today on the assumption that our students will have a calculator available whenever they need it.

So our first task is to ensure that they know how to use their calculators properly. Without teaching they may never learn how to correct "keying mistakes" simply and may spend their time pressing the clear key over and over again. They also need to be taught the methods for solving problems that are most appropriate when a calculator is available.

These methods are often radically different from those which one would use without a calculator so a good deal of research and experiment must go into finding the best methods to use in solving problems.

But anyone who wishes to become proficient in the use of numbers needs also to have what we will call a "number sense". This includes being able to work very simple number problems in the head and having a "feel" for the size and significance of a number.

In the West, until recently, the teaching of algorithms like long multiplication and division ensured that most children acquired a reasonably good grasp of mental arithmetic, and those who did not were generally considered to be failures. With the coming of the calculator those algorithms became unnecessary for their own sake and many people fear that abandoning them will result in children no longer acquiring "number sense".

It is I believe largely for this reason that many educationists are hesitant in allowing calculators into the classroom. We must first find some alternative way of teaching "number sense", then I believe the calculator will be allowed in to fulfil its proper role in the teaching of mathematics from the earliest stages.

Papua New Guinea with its 250 different traditional counting systems was virtually non-numerate in the Western sense until recently. Then the "modern mathematics" movement in the '60s and '70s led to the temporary abandonment of the teaching of mental arithmetic. So the situation here now is very much what some teachers fear the West might become if calculators were allowed freely into the classroom.

We in Papua New Guinea are thus in a good position to find out what sort of teaching can take the place of the traditional arithmetical algorithms. Elsewhere they can put off the need for change by keeping calculators out of the classroom. Here the damage is already done and the need to find an alternative way of teaching "number sense" is urgent.

Aims

The aims of this course are:

(1) to teach the correct use of the calculator

(2) to teach the most appropriate techniques for solving arithmetical problems given the availability of a calculator,

(3) to develop the number sense of the students through the teaching of appropriate facts, concepts and techniques to be carried out mentally without the calculator. This involves the experimental use of the following:-

(a) ensuring that basic addition and subtraction number facts are known

(b) providing alternatives within the course for those who are and those who are not able or willing to learn their multiplication tables.

(c) emphasising the importance of place-value eg by adding and subtracting numbers like 50, 700, 2000 rather than just 5, 7 and 2.

(d) making much use of the concept of a range, which involves knowing whether or not a number is between two other numbers, and also whereabouts in the range the number may be.

(e) providing techniques for finding possible ranges and estimates when adding, subtracting, multiplying and dividing.

(f) endeavouring to convey the concept of percentages by basing mental calculations and estimates on the use of 1%, 10%, 50% and 100%.

(g) developing the concept of proportion as the next most important arithmetical tool.

(h) approaching the problem of "rounding" realistically, using all appropriate methods of dealing with the non-integral numbers that occur frequently on the calculator and pose a serious problem when determining procedures for estimating.

Form of the Course

The Calculate and Estimate course is based on a series of 20 teaching and working units each recorded on one side of a C-60 cassette.

Each unit is supported by a Test and a MemoSheet. The Memo-Sheet, which may cover several units, summarises the teaching in each unit.

The whole course can thus be used on an individual self-paced basis, although as with all such courses the availability of some form of personal tutorship is likely to be important.

A "Teaching Manual" has also been prepared, to provide the additional information and examples needed by a class-teacher.

It is this combination of class-teaching with the possible reinforcement through the use of audio-tapes, that was the subject of the experimental course at the Administrative College of Papua New Guinea from March 7 - 11, 1983.

CONTENT

Note: (1) Fuller details are given in the Memo Sheets.

(2) Units 1 - 15 are only concerned with whole numbers.

(3) All work is done "mentally" and no "working" is allowed except where indicated.

Unit 1: Introduction to the Calculator

Instructions for the basic use of the EL230 (or EL220) calculator and correction of "keying" errors.

Unit 2: Addition (1)

Learning, and using the constant function on the calculator to practise, the sums of numbers up to 9 with 0, 1 and 2, and those that add up to 10 or 11.

Unit 3: Addition (2)

Learning and practising the rest of the number bonds up to 9 + 9.

Unit 4: Addition (3)

Adding a one-significant figure number (ie a number with only one non-zero figure) to any other number mentally and giving the answer in the correct order, starting with the first figure in it.

Unit 5: Addition (4)

Finding a possible range for the total of any set of numbers.

Adding a set of one-digit and two-digit numbers.

Using the memory of the calculator to add an array "across and down" and check with the Grand Total.

Checking totals of individual lines or columns of an array using the Possible Range.

Unit 6: Addition (5)

Checking and correcting totals of arrays, including addition modulo 10 to check the last figures.

Unit 7: Subtraction (1)

Learning the number bonds to 9 + 9 as subtractions.

Subtracting two-digit numbers which differ by less than 10.

Unit 8: Subtraction (2)

Subtracting any one-significant figure number from any other number and reading out the result in the correct order.

Subtracting numbers up to 10 and numbers over 90, from 100.

Unit 9: Subtraction (3)

Subtracting multiples of 10 from 100.
Subtracting any other number from 100.

Finding an estimate for the result of any subtraction.

Finding a possible range for the result of any subtraction.

Unit 10: Means

Using the constant function on the calculator to learn and practise the results of doubling and halving simple numbers.

Giving the result of halving an odd number as a range between two consecutive numbers.

Finding the mean of two numbers on the calculator as half their sum.

Finding the mean mentally by halving the difference and adding it to the smaller number.

Estimating the mean of any two numbers using their estimated difference and giving the result as an estimate (if only even numbers have to be halved) or as a possible range (if an odd number has to be halved).

Unit 11: Multiplication

Using the constant function to learn and practise the multiplication tables to 9 x 9.

Multiplying any number by a one-significant figure number, using carrying figures if desired and writing the answer "backwards" ie from the end first.

Finding a possible range for the product of any two numbers.

Using "Low/medium/high" to estimate where in the possible range a product will lie.

Unit 12: Division (1)

Using multiplication by a fraction with a 1 as numerator as a shorthand for an instruction to divide.

Dividing any number by a (smaller) one-significant figure number and giving the result (if not exact) as a one-significant figure range. If however the first figure obtained is a 1 a second figure is also required.

Unit 13: Division (2)

Finding a possible one-significant figure range for the result of dividing any number by any smaller number. If however the first figure is a 1 a second figure is also required.

Unit 14: Percentages (1)

Revision of alternative methods of giving the result of a division: rounding down, rounding up or giving it as a range.

Giving the rounded down result of dividing by 2, 10 or 100.

Finding 1%, 10%, 50% or 100% of a number, in rounded down form.

Finding a possible range for any percentage of any number by using the above "benchmarks" and using "Low/medium/high" to determine where in the range the answer will lie.

Using the calculator to find a given percentage of a given number.

Unit 15: Percentages (2)

Finding a possible range for the percentage that one number is of another, using the above "benchmarks".

Using the calculator to find one number as a percentage of another.

Increasing or decreasing a number by 10% in easy cases.

Estimating the result of increasing or decreasing any number by a given percentage.

Using the calculator to find the result of increasing or decreasing a number by a given percentage.

Finding a possible range for the percentage by which a number has been increased or decreased.

Using the calculator to find the percentage by which a number has been increased or decreased.

Unit 16: Decimals (1)

The meaning of decimals as tenths and hundredths.

Rules for working on the calculator in kina (or dollars).
Rules of working on the calculator in toea (or cents).

Revision of Unit 6.

Unit 17: Decimals (2)

Rounding an answer given by the calculator, or giving it as a range between two consecutive numbers of toea, when working in kina or in toea.

Dividing money by a number, or by money.

Multiplying or dividing a decimal by 10 or 100.

Revision of Units 6 and 10.

Unit 18: Decimals (3)

Revision of units 11, 12, 13 for money.

Using the calculator to deal with metres and centimetres, metres and millimetres, kilograms and grams.

Unit 19: Proportion (1)

Using the calculator to find the price of one amount given the price of another.

Finding, or finding a possible range for, what you have multiplied (or divided) one number by to give another.

Finding, or finding a possible range for, the price of one amount given the price of another, using either

(a) "what you have multiplied the amount by", or

(b) "what you have divided the amount by", or

(c) "what percentage you have increased or decreased the amount by."

Noting that a series of 9's in the calculator display is probably an approximation for an "exact" answer, obtained by rounding it up.

There are many methods of estimating, not just one correct way.

Unit 20: Proportion (2)

The idea of "proportional sets", with their two basic properties.

Using the constant function on the calculator to find a proportional set when the multiplier is known, and also when the 'new' value of a particular "old" number is known.

Applying this to

(a) finding the numbers of a set as percentages of their total

(b) finding the angles for a pie chart

(c) drawing a block diagram without graph paper.

Rounding to the nearest whole number.

A Follow-on Course: "Understanding Statistics"

The original demand from colleagues at Laloki College was for a course that would enable our Business Development Officer trainees to "understand a page f statistics". An attempt was made to produce such a course in 1982 but it was very soon found that the necessary estimation skills had to be taught first.

Having prepared the "Calculate and Estimate" Course as described above, it then became possible to complete the work originally required. "Comparing numbers" is the main theme and this requires more sophisticated techniques than the ones provided in the "Calculate and Estimate" course: the concepts and basic skills are included but a straight forward and speedy application is lacking.

To meet this need a slightly improved technique for multiplication is introduced, in which an estimate for the product of any number with a one-significant figure number is produced. This simply involves multiplying the second figure to determine what has to be added to the product with the first figure to give the probable "start" to the answer.

The whole system is then simplified by using the "Low/Medium/High" concept developed in the Calculate and Estimate course, and making the rule that where one of the numbers in a product, or the divisor in a quotient, is "Low" (ie having a second figure 0, 1 or 2) or "High" (having a second figure 7, 8 or 9) then it will be replaced by the nearest one-significant figure number. If however neither number in a product, or the divisor in a quotient, is in this sense "High" or "Low", then the "range" technique developed in the Calculate and Estimate course is adopted. In this case however the mean of the range can be used as the estimate.

This procedure should give an estimate with a maximum error of about 40%,* which could be reduced still further by using the 12 times table to reduce the error at its most critical point.

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* If the "traditional" method of approximating with "the nearest 1 significant figure number" is used then the true answer, eg with 1.49 x 1.49, may differ from the estimated answer by more than 120% (of the latter). I hope shortly to make a brief study of the possible and likely percentage errors for the different methods of approximation I have been using.

This follow-on course entitled "Understanding Statistics" is in course of preparation and when it is completed it should provide the actual practical skills of estimating for multiplication, division and percentages, for which the groundwork is laid in the "Calculate and Estimate" course.

Preparation

Materials for the whole course were prepared, with Memo-Sheets, "A" Tests, Manual and each Unit taught on one side of a C-60 audio cassette. The Librarian had kindly arranged to have a supply of 6 tape recorders (with ear phones) available with 5 cassettes on reserve and 5 more available on loan. I myself kept a further 15 copies of each cassette.

The multiple copying of the 250 cassettes had taken 10 hours work at the Audio-Visual Centre at UPNG.

Leaflets advertising the course had been sent to Staff Development Officers of 46 Government Departments etc but due to delays in typing the envelopes these could not be got out till the beginning of March so prior to that I had personally visited 21 Staff Development Officers in Waigani and Konedobu. Advertisements had also appeared in the Post Courier and the Times of PNG.

Everyone spoken to had expressed warm interest in the combination of calculator and mental arithmetic skills and nearly all said they would be sending staff to the course, or would be asking me to conduct a course specifically for them.

(7.3.83)

The first day

By 8 am. 16 were present and a further 8 by lunch time. These included 3 who had not sent in application forms. Several who had been promised places by telephone did not turn up. A third officer from each of two departments had been refused places to keep potential numbers below thirty.

On arrival I gave them copies of Memo-Sheet 1 to look through and as soon as all had been registered and lent calculators (apart from 2 who brought their own) I taught Unit 1 very much as in the Manual.

I decided not to test this unit as I had a feeling that the difficulty in the test would lie in understanding and envisaging the questions, rather than in knowing what to do in real situations. In any case I suspect that most of these procedures for correcting keying errors on calculators are learnt during the course rather than through the formal teaching of them.

I did however set the "Initial Test in Mental Arithmetic " (ACIT 1) which I had prepared for use in the Administrative College and found that 20 minutes rather than the 30 minutes originally intended was about right. 8 of the 18 took up to a further 5 minutes knowing they would lose marks by doing so but presumably believing they would gain more in the time by continuing.

A number used scrap paper in spite of instructions to the contrary and where possible I collected this in.

I decided that this ACIT 1 made Tests 2A and 3A unnecessary, so we did some practise in adding two-figure numbers direct. I think most of them could probably be taught to add any 2 two-figure numbers and read out the answer without writing it, rather than the 1 figure number onto a 2 figure number as in the course. I then set Test 4A.

I taught Units 5/6, more or less as in the Manual, and set Test 5/6 but had to give a good deal of help to individuals, particularly in finding the possible ranges. 10 of the 21 finished the test (including corrections of some questions suggested by me) in about 40 minutes, at which time we broke for lunch.

In the afternoon we started with the subtraction game: 90 cards with the number bonds to 9 + 9 in subtraction form. It would have been better if the single figure ones with answers 0 and 1 had been removed, but I heard plenty of wrong answers to the other questions. They took it in a good spirit however and we played in groups of 4 or 5, one holding up the card and giving it to the person who called out the correct answer first. We played a second round after grouping together in 2 new groups the best 2 from each group. (I have subsequently prepared similar cards for adding and subtracting any 2 two-digit numbers, for experimental use by Patrick Boi at Laloki).

I described the methods of subtracting by "making up to the next multiple of 10" and "change for a kina*" (by making the first number up to 9 and the second up to 10) and then explained the method of estimating subtraction as in Unit 9. I think I should have spent longer on the easy ones before dealing with the complications which occur when the first figures on the bottom line are the same as those above, or are missing. But they seemed to understand and several got the idea of finding the least possible answer by making the top number as small as possible and the bottom number as large as possible, etc. So I set test 9A and then went onto begin the teaching of "means".

We had agreed that instead of having the half-hour break from 2.30 - 3.00 and continuing for another hour afterwards we would work through till 3 pm by which time we were all pretty exhausted and hot as the fans had stopped with a power cut. I urged them to spend the remaining hour at the Library using the tapes and tape recorders there (but I do not believe any did). 4 bought calculators (K5.50*) and 6 bought cassettes (K1.30*) mainly units 9/10 but one had arrived late for unit 1 so bought that. (In all, 9 bought calculators and 8 cassettes were sold during the course.)

In the evening I marked the three tests they had done and was disappointed in the results of Tests 5/6A (the Possible Ranges) and Test 9A (Estimating subtractions) so I decided to prepare "B" Tests for these. Thanks to the plain paper copier at Laloki College I was able to produce copies before leaving for the Administrative College next morning.

* Papua New Guinea's Kina and toea correspond to Dollars and cents.

(8.3.83)

The Second Day

I gave out the three Tests they had done, went over in detail the Possible Ranges for addition and subtraction and set the 5/6B and 9B Tests. There was just time to have another go at the Means before 9.30 am and we finished it off at 10 am with Test 10A.

Moving onto multiplication I explained how to set the calculator with 2 (+) (=) to give the 2 x table and 2 (×) (=) to practise it. We did about 10 examples of multiplication on the board, starting with the possible ranges, then the means and finally the "Low/Medium/High" estimates. I then put another six on the board and put the solutions up when most of them had done them. Another 6 were left for them to complete over the lunch hour.

After lunch they did Test 11A. I introduced the procedures for division and they did Test 12A. I went over the more complex process required for Test 13A but they were too exhausted by 3 pm to take that test.

Marking their work in the evening I was pleased to find that the majority seemed to be grasping the work satisfactorily. Two or three did not know their tables well enough and about 6-8 failed to divide correctly by 10, 100, 1000 and give the answer (when not a whole number) as a range. I did not however feel it was necessary to set B tests this time. With Test 5/6B it appeared as though those who had understood it were all right anyway while the few who had not, tended to be even more confused.

(9.3.83)

The Third Day

I spent an hour going over Tests 5/6B, 9B, 10A, 11A, 12A. In the course of it we had a long discussion about possible ways of overcoming a mistake caused by putting (+) instead of (M+) at the end of totalling a column of numbers. After learning a lot about the things you could <u>not</u> do, and accepting the fact that you <u>could</u> press (C) and do the whole column again, I eventually explained the 0 (M+) solution. The questions and answers demonstrated clearly the difficulty in any theoretical approach to the use of the calculator: a rule of thumb was as much as most of these students could manage at this time.

The finding of the upper end of the possible range for division by a 1 significant figure range produced the expected difficulties and I did not spend too much time on Test 13A: only a few could do it.

The first test of percentages, Test 14A, however really surprised me. They again had difficulty in dividing by 10, 100, 1000. In the percentage unit I had explained that we would only "round down" which made it much easier, but even so, when I had explained that finding 1% meant dividing by 100 which meant crossing off 2 figures, they still failed over and over again to carry out this simple process. They had as much trouble with the corresponding rule for 10% and eventually I stopped them all and went over another 8 examples showing how to find the possible range for different percentages using only 1%, 10%, 50% or 100%. Not only did many of them seem unable to carry out the procedures, but it was clear that many of them did not know what they were trying to do. It did seem however that these procedures really were the best way of developing the concept, so I persisted.

Before attempting the next test however I was determined to do the reverse process very thoroughly in the hope that the ideas would stick. To determine what % one number was of another they actually worked out 1%, 10%, 50% and 100% of the "other" number except that we saved trouble over the 50% by writing only the first figure and dashes for the other figures, unless we needed to know them.

Most but not all could then see where the particular number fitted and could thus determine the possible range for the answer, 10 - 50% etc.

I left them struggling with more of these over the lunch hour. At least they should be able to find 1%, 10% and 100% of a number after this.

After lunch I went over the questions and then over the various different types of question in Test 15A. Eventually I set the Test and went round helping individuals as usual. With one of them this frustrating conversation occurred: What is 1% of 795? 7 (success!). Is 421 more or less than 7? Less. Are you sure? No, More (naturally - it had to be). So 421 is more or less than 1% of 795? Less. (Despair). Later: 50% of 795 is ... ? No answer. 7 ÷ 2 is? No answer. How many 2's in 7? 9.

But all students were not like this, 11 out of 23 got nearly all of Test 14A right, so clearly the method used is possible. What is arguable is whether there is some better way of developing the concept of percentage than the one I have chosen, namely that of learning to handle a few "easy" percentages and treating all other percentages as "between" these. A more orthodox approach is being planned for the "Understanding Statistics" course but as it depends more on multiplying by one number and dividing by 100 etc it is more dependent on a knowledge of the multiplication tables. If they have to struggle so hard to "know" 50% when it is a half, they are not going to find 8% easy to "understand" if it is 8 "times it" divided by 100. An additional reason for the current approach is that it only requires a knowledge of the 2 x table: this course has been designed to cater for those who do not know their other tables as well as for those who do.

(10.3.83)

The Fourth Day

I suppose it is good for a teacher to be shocked occasionally. I had imagined that place value would be basically understood by anyone who had reached Grade 10 and had attended 3½ days of this course. It was therefore with considerable chagrin that I found that one of the students still could not write down what 45 tens were. After multiplying it out he discovered that it was 450 but I discovered that he still thought that 7 tens were 700 and I had to teach him the rule about putting a zero on the end. Admittedly this particular student had scored the record number of 31 mistakes in Test 5/6B and had missed at least two part-days of the course, but one is driven to wondering what, if anything, should be done about such people.

The rest of the morning however had been pleasant, teaching a responsive class, although clearly <u>all</u> had not been responding. We had gone over every question in Tests 13A, 14A and page 1 of 15A. They had then done the calculator parts of Test 15A and had spent a long time revising addition, subtraction, multiplication and the use of the calculator on Kina and toea, m and cm, kg and g, m and mm.

I set Test 16A for the last half-hour before lunch and some of them understood it.

We had a bad afternoon. I thought they had at least learnt how to find means, with their excellent responses to questions, but on being tested it seemed that a lot of them had forgotten. They were also confused by the decimal point and by the alternatives of working in kina or toea. It is difficult to make these things plain except by examples and I thought we had done enough.

The procedure for estimating a product was again revised as were the procedures for estimating the result of dividing. Everyone seemed happy so I set Test 18A, only to find they were by now so confused that they crossed off zeros when multiplying and seemed to have forgotten that K8.96 was in the K8 - K9 range and that 8 x 30 was 240.

I stopped them in the middle of the test and went over it again in detail using other example. The "adding one" at the upper end of the range for division also, not surprisingly caused problems. (eg to divide 275 by 46 we divide first by 50 to find the "least possible", 5, and then by 40 to find the "greatest possible", but for this we must "add one" giving 7, not 6: see Conclusions .)

(11.3.83)

The Fifth Day

I spent a long time going over Tests 16A, 17A and 18A, then gave them the "Initial Test" ACIT 1 to see if they could improve on the scores obtained on the first day. I was not really happy however because it was precisely the same test although I assured them that some changes had been made. The questions in page 3 in particular would be too easily memorable.

I also issued Assessment Forms on which I requested comments on the course and asked them to return these to me before the end of the day.

I issued copies of 3ANCS 5.6 (a sheet produced some time before) to use as teaching material for finding the prices of different quantities "at the same rate" by proportion and they seemed to understand both the calculator method and the "easy multiples" method for finding the prices, but I decided it was quite inappropriate to use our crude methods to estimate the price eg for 980g given the price for 280g. The wide possible range one would obtain would make it unlikely to be of any practical value. This should be left until the more exact methods of estimation are available in the "Understanding Statistics" course, although even then a 20% error (?) is possible and this would render the method useless in most cases where one was comparing prices in a super-market.

At the end of the morning I explained the constant function method for converting currencies and finding other proportional sets. A few actually drew accurate pie charts and block diagrams for Test 20A and the enthusiasm extended to doing this over the lunch hour. I allowed them to keep their answer papers to this test although I had firmly collected all other answer papers.

COURSE MAKES NUMBERS COUNT

Mathematics lecturer Mr Allen Edwards shows Vele Terry, from South Pacific Brewery, how to calculate.

Mr Edwards, from the Administrative College in Port Moresby, was teaching at a "calculate and estimate" course. Twenty-four people from government departments and private firms completed the week-long course at the college on Friday.

They used calculators and tape recorders to improve their "sense of numbers," said Mr Edwards.

"I believe this course is a turning point in mathematical education because it is the first time a basic numeracy course has included the use of calculators and estimation skills," he said.

"This course has been one of the most interesting I have run in 36 years of teaching mathematics."

ANR 22

Courtesy of the Post Courier: 18 March 1983

During the morning the Director had welcomed my suggestion that the press be invited to the Presentation of Certificates at 1.30 pm and that they should be given copies of the Brief which I had prepared for him.
Although all expressed enthusiasm the Post Courier and Niugini News arrived too late for the Director's excellent little speech and the NBC did not appear at all. Photographs however were taken and I answered questions to the best of my ability.

Test Results

RESULTS OF TESTS taken by 24 Students on the first "Calculate and Estimate" Course.

TEST	No. of Possible Errors	MEANS of NUMBERS of WRONG ANSWERS. Numbers after + are MEANS of NUMBERS of QUESTIONS NOT ATTEMPTED. Numbers in ( ) are standard deviations.		
		Group A (n = 7/8)	Group B (n = 7/8)	Group C (n = 5 - 8)
4A	41	1.3 (1.3) + 0.1 (0)	2.7 (1.0) + 0.3 (0)	1.7 (1.9) + 7.0 (3.8)
5/6A	47	1.6 (1.5)	6.1 (3.0)	8.1 (2.7)
5/6B	47	2.4 (1.4) + 2.1 (4.2)	7.1 (4.7) + 8.7 (4.3)	18.2 (9.5) + 12.5 (7.4)
9A	45	8.0 (4.9)	10.4 (7.8)	15.8 (7.1)
9B	45	2.0 (2.4) + 0 (0)	4.0 (3.9) + 0.5 (0)	10.8 (3.2) + 1.1 (0)
10A	12	0.9 (1.1) + 0 (0)	3.6 (2.4) + 0.3 (0.7)	4.1 (2.3) + 2.3 (2.4)
11A	66	2.6 (2.3) + 2.0 (4.8)	4.2 (1.9) + 2.7 (2.1)	10.2 (5.8) + 11.2 (5.4)
12A	53	2.6 (2.5) + 2.0 (5.4)	10.1 (4.7) + 4.3 (5.4)	18.4 (2.5) + 14.4 (8.4)
13A	27	5.9 (3.9)	11.6 (4.3)	15.6 (5.6)
14A	40	6.3 (5.9)	11.1 (5.3)	19.6 (2.1)
15A	22	6.1 (6.1)	16.0 (4.1)	19.2 (4.1)
16A	37	5.3 (3.0)	12.1 (3.8)	16.5 (5.3)
17A	12	1.6 (1.2)	3.3 (1.8)	5.6 (2.3)
18A	28	13.5 (7.5)	21.0 (2.8)	21.8 (4.5)
19A	9	0.9 (1.0)	3.5 (2.1)	5.3 (2.0)
No. of Tests Missed through absence		0.9 (2.1)	0.9 (1.4)	3.4 (3.4)

Notes on the above Table of Test Results

The test numbers correspond to the numbers of the Units. "B" tests are roughly comparable to the "A" tests, but different.

The 24 students were divided (for the purposes of this Table only) into three groups of 8: the "A" group had less than 100 errors overall in all the Tests, the "B" group had between 100 and 170 errors and the C group had between 170 and 226. (For this purpose only, estimated numbers of errors were assigned where a test had been missed and "Not attempted" questions were treated as half-errors).

The scores given are for the Numbers of Wrong Answers. Where answers were frequently omitted at the end of a Test due to lack of time, the numbers of these have been recorded separately as "Not attempted": these were NOT included in the numbers of Wrong answers. Where answers were omitted while answers were given to subsequent questions, these were included in the numbers of Wrong answers.

Where a student was absent for a Test his existence was ignored in calculating the mean and standard deviation for the Group.

The results of Test 20A were not recorded although a quick assessment of them showed that the A group mainly scored A's, the B groups B's and the C group C's.

Comments on the Table of Test Results

The idea of dividing the class into 3 groups for the purpose of this analysis was to try to ascertain whether the tests were appropriate to a minority or a majority of the students. Where the middle group (B) have scores close to the top group (A) one can assume that the test was appropriate for the upper two-thirds of the class. Where the scores of the middle group are closer to those of the lowest group (C) one would suspect that the Test (or the teaching leading up to it) was inappropriate for the majority.

Test 4A: this consisted of simple additions and the number of "Not attempted" questions in Group C show that their main weakness lay in being slow.

Test 5/6A: the mean score for Group B turned out to be close to that for Group C confirming my suspicion at the time that the work had not been properly understood by the majority. This was the reason why more teaching

and a new test 5/6B, was given. The results of this new test showed an overall decrease over those of 5/6A but this is not as serious as it would appear since plenty of time and a good deal of individual help had been given during Test 5/6A, whereas the B test had been rushed with little help given. The B Group were now nearer to the A Group while the C Group had became substantially worse, suggesting that these weaker students may even have been more confused than before.

Test 9A showed a higher level of mistakes than I had considered acceptable and Test 9B confirmed that this position had been rectified by further teaching.

The results for Test 10A (of which the first 3 questions were omitted) showed a tolerably good grasp of the method of finding means with all but 2 students getting at least 6 out of 11 right.

Test 11A was on simple multiplication and estimates: the weaker students as usual were slow. Two of them clearly did not know their tables properly. Otherwise the main errors came when multiplying by multiples of 10, 100 or 1000 and in determining the estimates by the "Low/Medium/High" method.

In Test 12A most of the errors lay in dividing by multiples of 10, 100 or 1000.

Test 13A with 3 parts to each of 9 questions on estimating divisions showed a more-than-50% success rate for all but 7 students.

Test 14A with 40 answers on finding or estimating given percentages also showed a more-than-50% success rate for all but 4 students, but Test 15A with 7 questions on finding the % given the numbers and 15 on % changes showed that only 10 scored more than 50%.

Test 16A showed a similar lack of general mastery of the use of the calculator and estimation with kina and toea.

Test 17A was on multiplying money by 10, 100, 1000 and finding means: all but 3 got more than half of the 11 questions right.

Test 18A was the mixture of multiplication and division where confusion reigned (see "the Fourth Day").

In Test 19A six hard questions on proportional answers were deleted · leaving 9 for solution by the calculator or mentally. All but 7 got over 50% correct.

In all, the 24 students missed 42 out of 384 or 11% of the tests through absence. Only one was absent for half the number of tests, and did not receive a Certificate at the end.

RESULTS of an "INITIAL TEST" (ACIT 1) used as a Pre-and Post-Test.

Qu Nos.	Topic	No. of Possible Correct Answers	Means of Numbers of CORRECT answers. Numbers in ( ) are standard deviations.					
			Group A (n = 6)		Group B (n = 6)		Group C (n = 5)	
			Pre-	Post-	Pre-	Post-	Pre-	Post-
1-5	Simple + - x ÷	50	44.2(2.5)	47.0(2.5)	42.8(2.1)	46.7(2.2)	36.8(5.0	41.4(6.5)
6-9	Means, Proportion, %, % change, Biggest and smallest of 4 big products.	10	4.5 (3.0)	5.7 (3.4)	4.0 (2.2)	4.0 (2.0)	2.2(1.6)	3.6(1.8)
10	Estimates for + - x ÷ %	12	3.5 (2.1)	3.7 (2.5)	3.0 (1.8)	2.0 (2.1)	1.8(1.3)	1.2(1.8)
Extra Minutes spent on the Test (inexcess of 20 minutes)			1.7 (2.6)	0	2.5 (2.7)	0	2.4(2.5)	0

Comments on the Pre-and Post-Test (see Table above)

The test used for this was one that had been designed for a very different group of students and was not really satisfactory.

Questions 1-5 included many very simple additions, subtractions multiplications and divisions in which failure to round off a division correctly to the nearest whole number resulted in a possible 3 errors and other errors were mainly in division by 30, 50, 100 or 1000. All groups show an improvement but this is not particularly significant as there was no control over the actual time spent on this part of the paper.

Questions 6-9 were a miscellaneous collection and as they were the same questions Pre-and Post- answers could have been remembered.

Question 10 was asking for estimates. The marginal deterioration (except in the top group) might be construed as a failure. In fact the main failure lay in the nature and administration of the Test.

Of the 17 students who attempted the addition and subtraction estimates 12 used the methods taught, and nearly always obtained correct answers. The 5 who simply totalled or subtracted in the traditional manner also obtained answers near enough to the exact ones to have them counted as correct estimates. The advantages accruing from estimating were thus only in the saving of a minute or two, and such a saving was insignificant in a 20 minute test with 60 questions preceding these. Furthermore in the Pre-test a number had been allowed up to 5 minutes extra, so they could do these questions more easily by traditional methods in the Pre-Test.

Of the 9 students who attempted the multiplication, division and percentage estimates, 4 in Group A got 10 out of 17 right while 5 in Groups B and C got 1 right out of 13 attempted. No one attempted to do them by "traditional" methods.

The fact that so few correct results were obtained by the "new" methods was clearly due to the time factor: the procedures are still somewhat tedious even if they are quicker than long multiplication and division. In fact the longer time allowed in the Pre-Test resulted in more marks being scored by long multiplication than were gained by using the "new" methods, with a shorter time in the Post-Test.

Finally of the 17 who attempted question 10 in the Post-Test, 4 (including the brightest student of all) had not taken the Pre-Test due to late arrival, so their scores were not included in the Table above.

Given all these factors it is clear that the results of this test are of little value. The only conclusion to be drawn from them is that any attempt to test the results of a course like this must be very careful to give credit for any time saved by using the new methods. Tacking a dozen questions on to the end of a long paper on easy mental arithmetic is NOT a suitable method.

TABLE of INFORMATION obtained from the APPLICATION FORMS

	Group A	Group B	Group C
Department/Branch Numbers of students in ( ).	DPI (6) Nat.Statistics Off.(2)	DPI (4), PSC (1) Health (1) Nat. Statistics Off. (1) Nat. Arts School (1)	DPI (3), Health(2 East Sepik (1) Min.& Energy (1) SP Brewery (1)
Substantive Status; Acting status given after/; Not stated -.	CC1/4, CC3, CC4, CC5, CC5/6, CC6, CC6, CC6/7	CC1, CC1/4, CC3, CC4, CC5, CC5/7, CC6/8, -	CC1, CC2, CC3, CC3, CC4, CC4/5 CC6/8, -
Years in Public Service	mean 5.8, s.d 5.3	mean 4.9, s.d 3.8	mean 8.0, s.d 5.2 (excluding 1 in private enterprise)
Age in Years	mean 27, s.d 4.2	mean 26 s.d 6.3	mean 27, s.d 7.4
Education Grade completed. Number with this grade in ( )	8 (1), 9 (1), 10 (3), Higher Tech Cert (1) 2 years UPNG (1), B.Sc (1)	9 (2), 10 (4) PSHC (1)	6 (1), 9 (1), 10 (5)

Comments on Information obtained from Application Forms

The variety of Departments represented was pleasing: the larger number of officers from the DPI was due to separate entries from Konedobu and Laloki Research Station of which the Officer-in-Charge had originally stimulated the whole operation for the benefit of one officer, who had acted as guinea pig for some units and then attended the course: Group A, Grade 9.

There is a reasonable corre lation between the Group, the officer-status and the educational grade reached.

The very wide range of education, from Grade 6 to B.Sc would account for many of the problems noted in this report. The fact that all did form a reasonably cohesive and teachable group however suggests that the sort of mathematics here presented was in fact as new to the most educated as to the least. In other words the years of education between Grade 6 and B.Sc had not made all that difference to number-sense or the ability to use a calculator.

The duties for which the students hoped the course would improve their capabilities included the following: ordering, purchasing, ledger control, budgetting, control of expenditure on travel, accommodation etc, preparation of solutions, culture of samples, enumeration of bacteria, calculation of amounts of ingredients, seed distribution, examination of claims submitted, assisting the salary section, students' pay preparation, maintaining records, accounts, registers, tables, schedules, listings etc, making and checking calculations, the duties of a costing clerk, surveys of cash and food crops, maintaining stocks, doing monthly status reports, compiling statistical figures, keeping records on bees, assay of sera, use of graphs, percentages, means etc in biochemistry, assisting with the Divisional budget, raising leave warrants, providing estimates for the quarterly budget, disease statistics, keeping manpower records and coding information for the computer, recording vegetable trials, leasing property, preparing the Branch annual estimates, and financial quarterly review, reconciling them with computer printouts, coding completed survey forms, compilation and extraction of statistics, processing salary entitlements, leave pay, resumption pay, terminations, superannuation benefits etc.

The list is overwhelming: one can only hope that some contribution has been made to the work in each of these many fields.

The Students' Assessment of the Course

22 students completed and returned the "comment" forms offered to them on the last day.

"Did you feel the course was worthwhile"? All replied "Yes".

"What in particular have you understood fully and will now use?" Two said "everything", one said "50/50 of the units.

The calculator was mentioned by 8, estimating by 6, means by 3, ranges by 2 and "fast mental arithmetic" by 1.

"What parts of the course did you find most difficult to follow?" Two said "nil", one said "Nothing was difficult to me but merely a lot of practise is essential". "Percentages were mentioned by 9, "decimals" by 7, "means" by 5, "ranges" by 5, "proportion" by 4.

Under "any other comments, or suggestions": six said they wanted to attend further courses like this one; eight thought the course should be longer, including five who specifically complained that the teaching has been too fast; five said they approved of the Memo-sheets and would have liked me to go through them before setting the test (I had hesitated to do this because of the unavoidable "wordiness" which I felt the majority would only understand if they could take their own time to do it). Five referred to their jobs, one suggesting the estimating work would be particularly appropriate for DPI field officers. One pointed out that he had learned things which he had not been taught at school, and another mentioned the lack of air conditioning in the classroom.

Summary and Conclusions

The course was designed more as a basis for developing number sense than as specific training for the calculation of estimates. In other words the development of concepts has taken priority over specific estimating skills. The follow-on course "Understanding Statistics" will provide more specific directions for estimating products and quotients. In doing so however the concepts of range, of "low/medium/high" and the mental arithmetic skills developed in this course will be vital ingredients to ensure that the processes used are understood and not merely learnt rote-wise.

This has meant therefore, a rather slower start to the work than some of the students might have wished. Indeed, to imagine that in one week one can teach more of this vitally practical mathematics than has been learned in many years of formal education, would be impertinent. It may however be true that one consequence of this course may be some re-thinking of the arithmetical content of High School syllabuses.

My main conclusion therefore is that one must not expect miraculous results and one will not then be disappointed. Many of the techniques taught will undoubtedly be forgotten as indeed some had been within 48 hours during the course. But if the course is as relevant as I believe it to be then there will always remain with the students a conceptual background which was largely lacking before, as well as some specific skills in mental arithmetic and calculator use which will remain if and only if they are used.

With that background therefore I would make the following relatively minor amendments to the course.

(1) The process for division involves taking the lower end of one range and the upper end of another: this is confusing and the way to it may be eased by introducing dashes for place-holders instead of zeros. Thus 875 ÷ 30 will be written 2 - instead of 20 - 30 and 875 ÷ 20 will be written 4 - instead of 40 - 50. The final result for 875 ÷ 26 will still be 20 - 50. This will also pave the way for further use of the dash as a place holder instead of the zero. It is more accurate in that it does not imply a bias towards a low number.

(2) The attempt to deal with percentage changes while using the present crude method of estimating percentages will be abandoned. I believe the mere concept of a percentage is so strange to most students that this is enough at one time. I am still convinced that the traditional method of relating a percentage to either a decimal or a fraction is much less likely to lead to true understanding than the "bench mark" method employed here. Like all assertions about conceptualisation however, this would be difficult to prove.

(3) The estimation of results obtained by simple proportion will be omitted, as indeed it was on this occasion. A full treatment really requires an understanding of percentage changes (in cases where the variable has changed only by an amount less than itself) and this is to be a major topic in the "Understanding Statistics" course.

(4) Where possible the range of ability level of students will be reduced. If the demand for the course is sufficient it should be quite possible to prepare a pre-test to determine the level of course required. This

may in any case be necessary when the version of the course (omitting most of Units 11, 12, 13, 15, 18) intended for those who do NOT know their multiplication tables is offered. A series of courses at different levels would be the ideal to aim at.

(5) Cards for "games" testing different levels of arithmetical skill need to be prepared. The only one used on this course was too simple, testing only the subtractions corresponding to the number bonds up to 9 + 9. There is an obvious use for a similar game testing the addition/subtraction of single digit numbers to/from two-digit numbers, and of two-digit numbers to/from two-digit numbers.

These may then be used to extend these skills beyond the limits currently referred to in this course.

(6) Relatively little use was made of the audio-tapes on this occasion although they were available in the Library and a number of students borrowed or bought copies from me to use at home.

I think the main reason for the lack of use of this important reinforcement facility lay in the fact that the course occupied full days. This meant that the students were pretty exhausted by the end of it and also that so many units had been covered that there just would not be time to reinforce them all that same evening before even more were encountered on the morrow.

This consideration suggests that it would be better to spread the course out over one day a week or over mornings-only or afternoons-only, a form which has in fact already been requested by the Staff Development Officer when asking for two special courses to be run for clerical staff in the Department of Education.

(7) A proper Pre-and Post-test will need to be designed if any statistical results are required. This however may not be easy if it is admitted that a main objective at this stage is the development of concepts rather than of specific skills. Testing reasonably complex arithmetical conceptualisation as distinct from testing the ability to carry out specific procedures, seems to the writer an almost hopeless task, particularly where language is part of the problem.

The course will be held at the Administrative College Waigani, from 8a.m. to 4 p.m., Monday to Friday, 7th to 11th March 1983.

Application Forms may be obtained from Student Administration at the College, P.O.Box 1216, Boroko.

Other enquiries may be addressed to Allen Edwards, The Numeracy Project, Laloki College, P.O.Box 1864, Boroko. Telephone 281060/ 281064.

The Administrative College of Papua New Guinea.
February 1983

CALCULATE

and

ESTIMATE

a one week course

"CALCULATE and ESTIMATE"

Most office workers today and many who do not work in offices could do their work better with two skills which they are not likely to have learnt at school.

* How to use a calculator correctly
  - — Most people only use + - x ÷ = and the Clear key
  - — They need to know about the memory, constant function, % and the Clear Entry key
* How to estimate i.e. find approximate answers
  - — To know when they have made a mistake on the calculator
  - — To develop a "number sense"

The Course consists of 20 units.

Unit	Content
1	*Introduction to the calculator; correcting errors*
2-6	*Addition: use of the constant function and memory on the calculator, adding mentally any one-significant figure number (eg 2315+400), estimating totals, totalling down and across a table and checking*
7-9	*Subtraction: subtracting mentally any one-significant figure number, estimating differences*
10	*Calculating and estimating the mean (average) of any two numbers*
11	*Estimating the result of multiplying two numbers*
12-13	*Estimating the result of dividing two numbers*
14-15	*Percentages: calculating and estimating a percentage and the result of increasing or decreasing by a percentage*
16-18	*Decimals: adapting the previous units to apply to money, metres, kilograms etc*
19-20	*Proportion: calculating and estimating the price of one amount given the price of another; using the constant function on the calculator to find proportional sets e.g. for pie charts and graphs*

* Each unit will be taught and tested

** Audio-cassettes will be available for those who need to work through a unit a second time

*** Calculators will be available on loan or for sale

For the Director of the Administrative College of P.N.G...11.3.83

BRIEF ON THE FIRST "CALCULATE AND ESTIMATE" COURSE, 7-11 March 1983

Course coordinator: Allen Edwards

The material used in this course has been developed over the past three years at Laloki College, but this is the first time it has been put together as a single course.

It is also the first time (as far as I know) that a mathematics course has been offered in P.N.G where the students have been able to reinforce their learning through a series of cassettes on a tape recorder.

I believe the course represents a turning point in mathematical education, perhaps even on a world-wide scale, in that it is (again as far as I know) the first time a basic numeracy course has included both calculator use and estimation skills.

The process of estimation involves many concepts that are only lightly touched on in most school syllabuses, but they are all of the greatest possible practical importance. One of the chief of these is the concept of a "range" and in particular of the "one significant figure range" e g that 368 is in the range 300 - 400. Another concept is whereabouts in the range a number may lie: is it "low, medium or high" in the range?

A related concept is the mean or average of two numbers. Another concept is a real understanding of place value, such as the fact that there are 27 hundreds in 2753. Another is the whole idea of percentage, leading to an understanding of the methods of finding percentages and percentage changes, either mentally or on the calculator.

Then again there are many skills which are inadequately developed today, particularly skills in mental arithmetic. I was horrified to discover that one student on the course did not know how to multiply a number by 10: many were unable to divide by 10, 100 or 1000. Too many found it hard to add a single figure number to a two-figure number and subtraction skills were particularly weak. "Halving" a number was often done incorredtly through uncertainty in the 2X table

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With all these skills and concepts to be taught or re-taught it is not surprising that some of the students seemed to suffer from a sort of mental indigestion by the end of the week, some things becoming muddled that had earlier seemed clear. It is difficult to see how one can overcome such a problem: a longer exposure to the work would obviously help but that would be expensive in manpower both on the part of students and teachers. We shall have to see if some simplification of the course is possible without losing its essential character.

Mennwhile, for a first attempt at a completely new type of course one can feel reasonably satisfied that it is on the right lines. No doubt it will be improved as further courses are run. There is also a second course which is being prepared to follow on from this one, improving the skills already gained here and applying them to the art of "Understanding Statistics", that is, being able to make sense of a page full of numbers.

If I may offer advice to the participants of this course it would be this. First to those who have found it hard and know they have not really mastered it: use the Administrative College Library. In it is a complete set of the tapes used for this course and some tape recorders. Could they find time to work through some of these units again in the cool and quiet of the College Library?

And to those who know they have mastered this course: practise what you have learnt in it. When you meet numbers in your daily work estimate the answers you need and use the calculator correctly when you need to. Then keep your eyes open for the follow-on course on "Understanding Statistics", probably next July or August.

In conclusion may I say that the course has been for me one of the most interesting I have ever run in 36 years of teaching mathematics. And it could be the beginning of something really important.